NORTHERN
SEPTEMBER 2018

GRDC GROWNOTES™

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

CEREAL RYE

SECTION 13

STORAGE

HOW TO STORE PRODUCT ON-FARM | STORED-GRAIN PESTS | AERATION DURING STORAGE | GRAIN PROTECTANTS FOR STORAGE

Storage

Key messages

- Rye is considered to be dry and safe for storage at 12% or lower kernel moisture. At this moisture content, loss of condition due to moulds or mites is unlikely.
- Rye that goes for milling and baking has to meet specified commercial and hygienic standards. Therefore, early harvesting and proper drying before storage are necessary.
- Cereal rye grain does not store well unless frequently treated for insect contamination.
- Seed germination drops rapidly when cereal rye is stored longer than a year.
- Moisture content and temperature of the grain during harvest determine how long rye can be stored safely. Drying and cooling of freshly harvested, moist, warm grain is an important operation that must occur before rye goes for processing or storage.

Drying and storage of cereal rye is similar to wheat. Rye that goes for milling and baking has to meet specified commercial and hygienic standards. Therefore, early harvesting and proper drying before storage are necessary. [1]

Rye should have 12% or less moisture content (MC) when stored.

It is important to follow guidelines on the safe storage to avoid grain deterioration. The MC and temperature of the grain at harvest determine how long it can be stored safely; i.e. without loss in quality or quantity. It is important to dry and cool freshly harvested, moist, warm grain before it goes for processing or storage.

Seed germination drops rapidly when cereal rye is stored longer than a year. [2]

IN FOCUS

Storing rye safely

Rye samples with moisture contents of 10.0%, 12.5%, 15.0% and 17.5% (wet basis) were stored for 16 weeks, with samples at each degree of moisture kept at 10°C, 20°C, 30°C and 40°C. Once a week, the researchers measured the germination rate and moisture content, and monitored visible mould on all samples. Every two weeks, they checked free fatty acid values (FAV). Every four weeks, they tested all samples for invisible microflora.

The germination rate decreased significantly as moisture content, temperature and storage period increased. The moisture content of the samples stored at 10°C increased with time, whereas that of samples stored at 30°C and 40°C decreased. Visible mould appeared in all the samples with 17.5% MC, and in all the samples stored at 40°C. The predominant fungi in almost all the samples in the study were *Penicillium* spp. and *Aspergillus glaucus*. Fat acidity value increased with increasing moisture content, temperature, and storage time.

The researchers determined that germination was the most sensitive, effective, and simple method of determining the condition of a grain bulk on the farm, as it proved to be a good indicator in its own right, and because it can be determined with no special training and expensive equipment. They developed safe storage guidelines for MC and

1 G Sathya, DS Jayas and NDG White (2008) Safe storage guidelines for rye. Canadian Biosystems Engineering, 50, 3.1–3.8, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.498.6611&rep=rep1&type=pdf

2 Alberta Agriculture and Forestry (2016) Fall rye production. Revised. AgDex 117/20-1. Alberta Agriculture and Forestry http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1269/$file/117_20-1.pdf

temperature were developed based on the drop in germination and the appearance of visible mould.

On this basis, rye with less than 12.5% MC stored at less than 20°C is safe for at least 15 weeks, whereas with rye with over 15% MC stored at 40°C growers have less than a week to complete drying and cooling (Figure 1). [3]

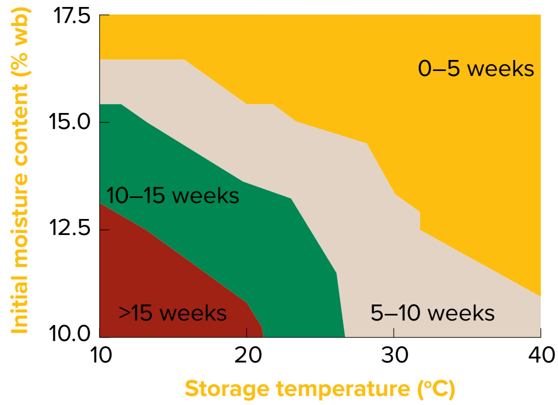


Figure 1: *Estimated safe storage life of rye based on 20% decrease in the initial germination and no visible mould. Periods of safe storage are indicated.*

Source: Satha, Jayas and White 2008

GRDC Stored grain information hub

Following the work already done through the Grain Storage Extension Project, the GRDC have funded another three years allowing grain storage extension to continue through to 2018.

The project aims to provide a stored grain information hub and equip growers with the skills and knowledge to enable best management practices of on-farm grain storage. Some exciting new resources to keep an eye out for under the new project will be an eLearning Manual, a smart phone App and an extension community of practice.

For more information on the grain storage extension project or to arrange a workshop in your area contact a member of the team.

- National Hotline 1800 weevil (1800 933 845)
- QLD and northern NSW, Philip Burrill philip.burrill@daff.qld.gov.au
- Southern NSW, VIC, SA and TAS, Peter Botta pbotta@bigpond.com
- WA, Ben White ben@storedgrain.com.au
- Project coordinator Chris Warrick info@storedgrain.com.au

MORE INFORMATION

Stored grain information hub

13.1 How to store product on-farm

On-farm grain storage takes a significant investment. Although many farms have older storage facilities that cannot be sealed for grain fumigation, replacing them with sealable silos may not be economically viable.

3 G Sathya, DS Jayas and NDG White (2008) Safe storage guidelines for rye. Canadian Biosystems Engineering, 50, 3.1–3.8, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.498.6611&rep=rep1&type=pdf

Growers might only plan to store grain on-farm for a short time, but markets can change, so investing in gas-tight sealable structures means you can treat pests reliably and safely and leave your business open to a range of markets.

Growers should approach storage as they would purchasing machinery: Growers spend a lot of time researching a header purchase to make sure it is fit-for-purpose. Grain storage can also be a significant investment, and a permanent one, so it pays to have a plan that adds value to your enterprise into the future.

> *Decide what you want to achieve with storage, critique any existing infrastructure and be prepared for future changes: A good storage plan can remove a lot of stress at harvest – growers need a system that works so they capture a better return in their system.* [4]

Agronomist's view

Mixed storage could be the solution. The strategy is to purchase a small number of sealable silos and use them to batch-fumigate grain prior to sale. This works because grain silos in the northern region are aeration-cooled for most of the time and only sealed for the purpose of fumigation.

VIDEOS

WATCH: Over the Fence: On-farm storage pays in wet harvest

There are several reason why growers might consider storing grain on the farm, including:

- improving harvest logistics
- taking advantage of higher grain prices sometime after harvest
- supplying a local market (e.g. feedlot, dairy, etc.)
- avoiding high freight costs at peak time
- adding value by through cleaning, drying or blending grain
- retaining planting seed [5]

In most cases, for on-farm storage to be economical, it will need to deliver on more than one of these benefits, and the benefits need to outweigh the disadvantages (Table 1). Under very favourable circumstances grain storage facilities can pay for themselves within a few years, but it is also possible for an investment in on-farm storage to be very unprofitable. GRDC's Stored Grain Information Hub has a cost–benefit analysis tool that can help growers decide what type of grain storage to have on the farm. [6]

4 GRDC. (2015). Ground cover issue 119 – Grain storage. Extension tailored for regional challenges. https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-119--Grain-storage/Extension-tailored-for-regional-challenges

5 GRDC (2015) Grain storage strategies in the northern region. GRDC, https://grdc.com.au/archive/key-issues/grain-storage-strategies-in-the-northern-region

6 Stored Grain Information Hub (n.d.) Grain storage cost benefit analysis template. GRDC, http://storedgrain.com.au/cost-benefit-template/

Table 1: *Advantages and disadvantages of grain-storage options.*

Storage type	Advantages	Disadvantages
Gas-tight, sealable silo	Gas-tight, sealable status allows phosphine and controlled atmospheres to control insects Easily aerated with fans Fabricated on-site, or off-site and transported Capacity from 15 t to 3,000 t 25 years or more of service life Simple in-loading and out-loading Easily administered hygiene (cone-based silos particularly) Can be used multiple times in a season	Requires foundation to be constructed Relatively high initial investment required Seals must be maintained regularly Access requires safety equipment and infrastructure Requires and annual test to check gas-tight sealing
Unsealed silo	Easily aerated with fans 7–10% cheaper than sealed silos Capacity from 15 t to 3,000 t Up to 25 year service life Can be used multiple times in a season	Requires foundation to be constructed Silo cannot be used for fumigation Insect control limited to protectants in eastern states and Dryacide® in WA Access requires safety equipment and infrastructure
Grain-storage bags	Low initial cost Can be laid on a prepared pad in the paddock Provide harvest logistics support Can provide segregation options Are ground operated	Requires purchase or lease of loader and unloader Increased risk of damage to grain beyond short-term storage (typically three months) Limited insect control options, with fumigation possible only under specific protocols Requires regular inspection and maintenance, which need to be budgeted for Aeration of grain bags currently limited to research trials only Must be fenced off Prone to attack by mice, birds, foxes, etc. Limited wet-weather access if stored in paddock Need to dispose of bag after use Single-use only

MORE INFORMATION

[Grain storage cost–benefit analysis template](#)

[Saving weather-damaged grain for seed](#)

[Prepare on-farm storage early to protect your harvest](#)

[Storage checklist](#)

[Grain storage – invest today for the system of tomorrow](#)

Storage type	Advantages	Disadvantages
Grain-storage sheds	Can be used for dual purposes 30 years or more of service life Low cost per stored tonne	Aeration systems require specific design Risk of contamination from dual purpose use Difficult to seal for fumigation Vermin control is difficult Limited insect control options without sealing Difficult to unload

Source: Kondinin Group

13.1.1 Silos

Cereal rye grain does not store well unless it is frequently treated for insect contamination. To minimise insect attack, the grain should be stored at less than 12% MC, preferably in sealed silos (Photo 1). [7] Treat the grain as it enters the silo and then check every 2–3 months for reinfestation by grain insects.

Photo 1: *It is important to pressure test all silos used on the farm, even those that are labelled as 'sealed'.*

Source: GRDC

Sealed silos offer a longer-term grain-storage option than grain-storage bags. Depending on the amount of storage required, silos will be more expensive to install than storage bags: as stored tonnage increases the capital cost of storage increases. Silos are depreciated over a longer time frame than the machinery required for the grain bags.

Among the advantages of using sealed silos to store grain storage are improved harvest management, reduced harvest stress, reduced harvest freight requirements, minimal insecticide exposure, and the opportunity to segregate and blend grain.

7 Stored Grain Information Hub (2014) Pressure-testing sealable silos. Revised. Fact sheet. GRDC, http://storedgrain.com.au/pressure-testing/

VIDEOS

WATCH: GCTV2: Pressure testing sealed silos

MORE INFORMATION

Pressure testing sealable silos fact sheet

GRDC Silo buyer's guide

Disadvantages include the initial capital outlay, the outlay required to meet occupational health and safety requirements, the additional on-farm handling required, and the additional site-maintenance requirements. [8]

Pressure testing

- A silo sold as a sealed silo needs to be pressure tested to be sure it's gas-tight.
- It is strongly recommended that growers ask the manufacturer or reseller to quote the AS2628 on the invoice as a means of legal reference to the quality of the silo being paid for.
- Pressure-test sealed silos upon erection, annually and before fumigating by using a five-minute half-life pressure test.
- Maintenance is the key to ensuring a silo purchased as sealable can be sealed and kept gas-tight.

In order to kill grain pests at all stages of their life cycle (egg, larvae, pupae, adult), phosphine gas concentration levels need to reach and remain at 300 parts per million (ppm) for seven days or 200 ppm for 10 days. This can only occur if the gas cannot leak out of the grain-storage space. The only way to determine if the space seals is to conduct a pressure test.

A silo is only truly sealed if it passes a five-minute half-life pressure test according to the Australian Standard AS2628. Often silos are sold as sealed but are not gas-tight—rendering them unsuitable for fumigation.

Even if a silo is sold as 'sealed' it is not sealed until it is proven to be gas-tight with a pressure test.

The term 'sealed' has been used loosely during the past and, in fact, some silos may not have been gas-tight from the day they were constructed.

However, even a silo that was gas-tight to the Australian Standard on construction will deteriorate over time, so it needs annual maintenance to remain gas-tight.

The importance of a gas-tight silo

The Kondinin Group 2009 National Agricultural survey revealed that 85% of respondents had used phosphine at least once during the previous five years and that, of those users, 37% had used phosphine every year for the past five years. A Grains Research and Development Corporation survey during 2010 revealed that only 36% of growers using phosphine applied it correctly, i.e. in a gas-tight, sealed silo (Figure 2). Research shows that fumigating in a storage that does not meet the industry standard does not achieve a high enough concentration of fumigant for long enough to kill pests at all life-cycle stages (Figure 3). For effective phosphine fumigation, a minimum of 300 parts per million (ppm) gas concentration for seven days, or 200 ppm for 10 days, is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. In the rest of the silo, gas concentrations are also reduced. [9]

8 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates

9 P Botta, P Burrill and C Newman (2014) Pressure testing sealable silos. Fact sheet. Updated. GRDC, http://storedgrain.com.au/pressure-testing/

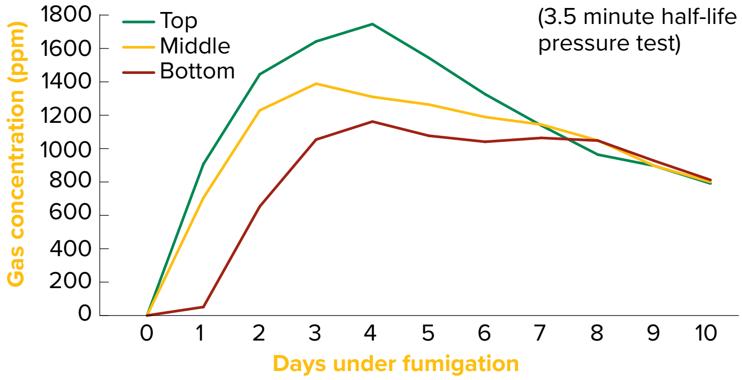


Figure 2: *Gas concentration in gas-tight silo is maintained for long enough to kill pests at all life stages.*

Source: GRDC

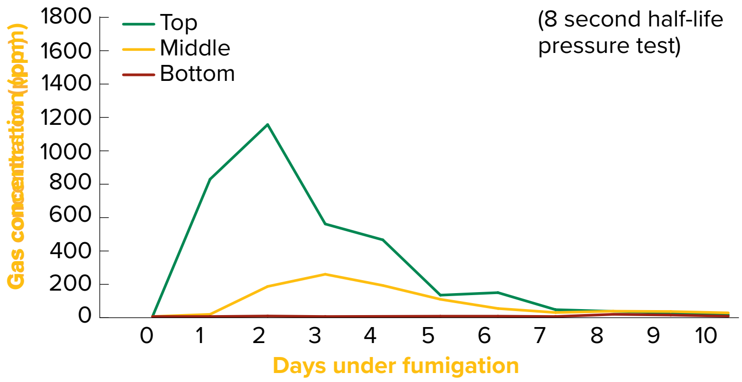
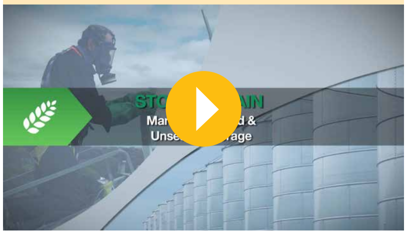


Figure 3: *In a silo that can't be sealed, gas concentration drops quickly and not all insects are killed.*

Source: GRDC

VIDEOS

WATCH: GCTV. Stored grain: Managing sealed and unsealed storage



MORE INFORMATION

Fumigating with phosphine, other fumigants and controlled atmospheres

It is recommended that sealable silos be pressure-tested once a year to check for damaged seals on openings.

There is no compulsory manufacturing standard for sealed silos in Australia. A voluntary industry standard was adopted in 2010, but not all silo manufacturers have adopted the standard. [10] Watch this GRDC Ground Cover TV clip to find out more.

13.1.2 Grain bags

Grain-storage bags are relatively new technology, and offer a low-cost alternative for the temporary storage of grain. They are made of a multilayer polyethylene material similar to that used in silage-fodder systems. Bags typically store between 200 and 220 tonnes of wheat, and are filled and emptied using specialised machinery (Phot 2). The bags are sealed after filling, creating a relatively airtight environment which, under favourable conditions, protects grain from insect damage without the use of insecticides.

10 GRDC (2010) National standard for sealed silos. GCTV2. GRDC, http://www.youtube.com/watch?v=iS3tUbJZI6U

VIDEOS

WATCH: GCTV extension files: Grain bags—best practice

WATCH: GCTV extension files: Grain bags—a grower's perspective

MORE INFORMATION

Successful storage in grain bags

The advantages of using grain-storage bags include the low capital set-up costs, improved harvest management, less harvest stress, reduced harvest freight requirements, minimal cost to meet occupational health and safety (OH&S) needs, reduced insecticide requirements, and the opportunity to segregate and blend grain.

Disadvantages include the need to dispose of used bags, bag deterioration, and the need to ensure bag integrity. Another disadvantage of this system, compared to longer-term structures such as silos, is that once the grain has been take out of the storage there is no asset value in the storage system other than for the bagging machinery. [11]

Photo 2: *A bag 100 m long can be filled in 30 minutes if there is a constant supply of grain.*

Source: Star Tribune

13.1.3 Monitoring stored grain

Whatever method is used to store grain on the farm, monitoring grain temperature and moisture content should occur regularly:

- Pests and grain moulds thrive in warm, moist conditions. Monitor grain moisture content and temperature to prevent these becoming problems.
- Use a grain-temperature probe to check storage conditions and aeration performance (Photo 3).
- When checking grain, smell the air at the top of storages for signs of high grain moisture or mould.
- Check germination and the vigour of planting seed held in storage.
- Aeration fans can be used to cool and dry grain to reduce storage environment problems.

It is vital to monitor grain moisture content to prevent pests and grain moulds from thriving. [12]

11 J Francis (2006) An analysis of grain storage bags, sealed grain silos and warehousing for storing grain. Holmes Sackett and Associates

12 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2017/05/Monitoring-stored-grain-on-farm-2017.pdf

Photo 3: *A digital probe is used to check grain temperature and aeration performance.*

Source: Plant Health Australia

13.1.4 Grain storage: getting the economics right

As growers continue to expand their on-farm grain storage, the question of economic viability gains significance. There are many examples of growers investing in on-farm grain storage and paying if off in one or two years because they struck the market at the right time, but are these examples enough to justify the expansion of on-farm grain storage for all growers?

GRDC's grain-storage extension team conducts approximately 100 grower workshops every year Australia wide, and it's evident that no two growers use on-farm storage in exactly the same way. Like many other economic comparisons in farming, the point at which storage might become viable is different for each grower. Depending on the business's operating style, the location, the resources the farm has and that are needed to install storage, and the factor that most limits profit increases, grain storage may or may not be the next best investment. For this reason, all growers need to do a simple cost–benefit analysis for their operation.

To make a sound financial decision, the grower needs to compare the expected returns from grain storage to expected returns from other farm investments, e.g. buying more land, a chaser bin, a wider boom spray, or a second truck, or paying off debt. They also need to determine if they can store grain on the farm cheaper than paying a bulk handler to store it.

Calculating the costs and benefits of on-farm storage gives the grower a return-on investment (ROI) figure, which can be compared with other investment choices, and a total cost of storage to compare to the bulk handlers.

The key to a useful cost–benefit analysis is identifying which financial benefits to plan for and costing an appropriate storage to suit that plan. People often ask: What's the cheapest form of storage? The answer is the storage that suits the planned benefits: if the farmer is seeking short-term storage for harvest logistics or freight advantages, they might choose grain bags or bunkers; if flexibility is required for longer-term storage, they might choose gas-tight, sealable silos with aeration cooling that allow quality control and insect control.

Benefits and costs

The best way to compare the benefits and costs is to work everything out on the basis of dollars per tonne (Table 2). On the benefit side, most growers will require multiple financial gains for storing grain if they are to make money out of it. These might include harvest logistics or timeliness, taking advantage of market premiums, freight savings, or cleaning, blending, or drying grain to add value.

The costs of grain storage can be broken down into fixed and variable. The fixed costs are those that don't change from year to year and have to be covered over the life of the storage. Examples are depreciation, and the opportunity or interest cost on the capital.

The variable costs are all those that vary with the amount of grain stored and the length of time it's stored for. Interestingly, the costs of good hygiene, aeration cooling and monitoring are relatively low compared to the potential gains the farmer gets back in maintaining grain quality. One of the most significant variable costs, and one that is often overlooked, is the opportunity cost of the stored grain, i.e. the cost of having grain in storage rather than having the money in the bank paying off an overdraft or a term loan.

The result

While it's difficult to put an exact dollar value on each of the potential benefits and costs, a calculated estimate will determine if on-farm storage is worth a more thorough investigation. If the farmer compares the investment in this to other investments and the result is similar, then they can revisit the numbers and work on increasing their accuracy. If the return is not even in the ball park, they've potentially avoided a costly mistake for a small investment in time. On the contrary, if, after checking the numbers, the return is favourable, they can proceed with the investment confidently.

Summary

Unlike a machinery purchase, grain storage is a long-term investment that cannot be easily changed or sold. Based on what the grain storage extension team is seeing around Australia, those growers who take a planned approach to on-farm grain storage and do it well are being rewarded for it. This is because grain buyers seek out growers who have a well-designed storage system that can deliver insect-free, quality grain without delay.

Table 2 is a tool that can be used to figure out the likely economic result of on-farm grain storage for each individual business. Each column can be used to compare various storage options including type of storage, length of time held or paying a bulk handler. [13]

Table 2: *Cost–benefit template for grain storage.*

Financial gains from storage		Example $/t
Harvest logistics/ timeliness	Grain price x reduction in value after damage % x probability of damage %	$16
Marketing	Post-harvest grain price – harvest grain price	
Freight	Peak rate $/t – post-harvest rate $/t	$20
Cleaning to improve grade	Clean grain price – original grain price – cleaning costs – shrinkage	
Blending to lift average grade	Blended price – ((low grade price x %mix) + (high grade price x %mix))	
Total benefits	Sum of benefits	$36.20
Capital cost	Infrastructure cost ÷ storage capacity	$155
Fixed costs		
Annualised depreciation cost	Capital cost $/t ÷ expected life storage, e.g. 25 years	$6.20
Opportunity cost on capital	Capital cost $/t x opportunity or interest rate, e.g. 8% ÷ 2	$6.20

13 C Warrick (2016).Grain storage: get the economics right. GRDC Update Paper, GRDC, https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2016/09/Grain-storage-get-the-economics-right

MORE INFORMATION

[Economics of on-farm grain storage: cost–benefit analysis](#)

[Economics of on-farm grain storage: a grains industry guide](#)

VIDEOS

WATCH: Over the Fence: On-farm storage delivers harvest flexibility and profit.

WATCH: Stay safe around grain storage.

Financial gains from storage		Example $/t
Total fixed costs	Sum of fixed costs	$12.40
Variable costs		
Storage hygiene	(Labour rate $/h x time to clean h ÷ storage capacity) + structural treatment	$0.23
Aeration cooling	Indicatively 23 c for the first 8 days then 18 c per month ÷ t	$0.91
Repairs and maintenance	Estimate e.g. capital cost $/t x 1%	$1.51
Inload/outload time and fuel	Labour rate $/h ÷ 60 minutes ÷ auger rate t/m x 3	$0.88
Time to monitor and manage	Labour rate $/h x total time to manage h ÷ storage capacity	$0.24
Opportunity cost of stored grain	Grain price x opportunity interest rate e.g. 8% ÷ 12 x number of months stored	$7.20
Insect treatment cost	Treatment cost $/t x number of treatments	$0.35
Cost of bags or bunker trap	Price of bag ÷ bag capacity tonne	
Total variable costs	Sum of variable costs	$11.32
Total cost of storage	Total fixed costs + total variable costs	$23.72
Profit/Loss on storage	Total benefits – total costs of storage	$12.48
Return on investment	Profit or loss ÷ capital cost x 100	8.1%

Source: GRDC

13.2 Stored-grain pests

Key points:

- Effective grain hygiene and aeration cooling can overcome 85% of pest problems.
- When fumigation is needed, it must be carried out in pressure-tested, sealed silos.
- Recirculation and ground-level applications have a role in effective, safe fumigation.
- Monitor stored grain monthly (even more regularly if possible) for moisture, temperature and pests.
- Combining good hygiene, well-managed aeration cooling and regular grain inspections provides the best foundation for successful grain storage.
- Darling Downs producers should achieve grain temperatures in storage of 20–23°C during summer storage, and less than 15°C in winter.

13.2.1 Prevention is better than cure

The combination of meticulous grain hygiene and well-managed aeration cooling generally overcomes 85% of storage-pest problems.

For grain storage, three factors provide significant gains for both pest control and grain quality: hygiene, aeration cooling and correct fumigation. [14]

13.2.2 Common species

Cereal grains include rye, wheat, barley, oats, triticale, sorghum and millet. The most common insect pests of stored cereal grains in Australia are:

- weevils *(Sitophilus spp.)—the r*ice weevil is the most common weevil in wheat in Australia
- lesser grain borer *(Rhyzopertha dominica)*
- rust-red flour beetles *(Tribolium spp.)*
- saw-toothed grain beetles *(Oryzaephilus spp.)*
- flat grain beetles *(Cryptolestes spp.)*
- Indian meal moth *(Plodia interpunctella)*
- angoumois grain moth *(Sitotroga cerealella)*

Most of them can be differentiated relatively quickly (Figure 4). [15] Another dozen or so beetles, psocids (booklice) and mites are sometimes present as pests in stored cereal grain.

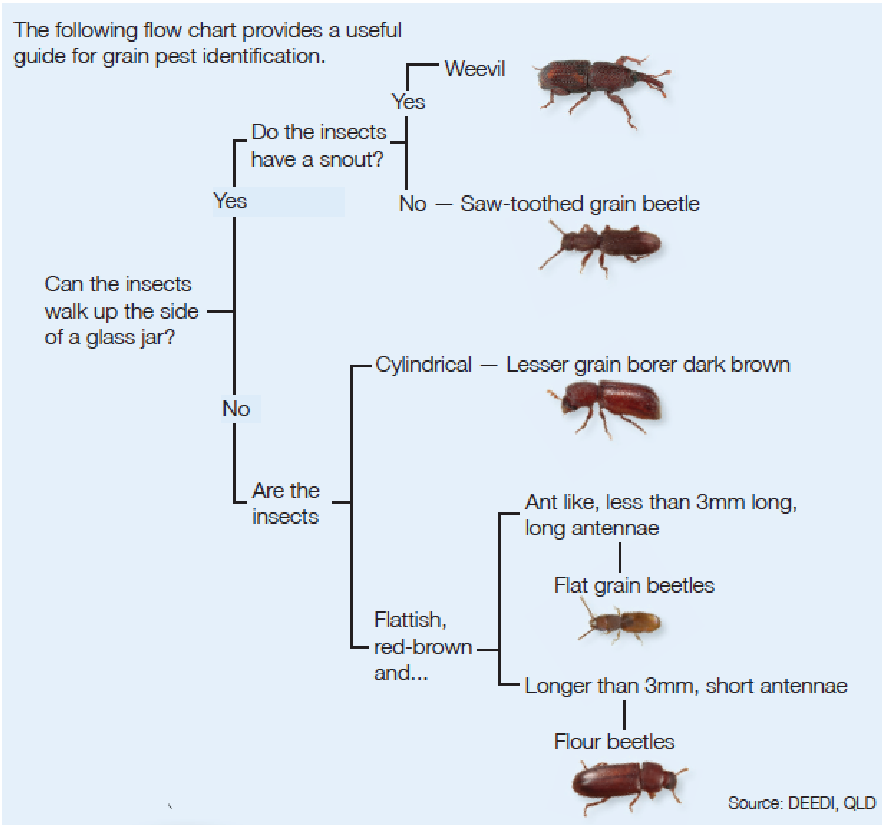


Figure 4: *Identification of common pests of stored grain.*

Source: GRDC.

MORE INFORMATION

Stored grain pests: identification—northern and southern regions

14 Stored Grain Information Hub (2016) Grain storage pest control guide: northern and southern regions. GRDC, http://storedgrain.com.au/pest-control-guide-ns/

15 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2015/11/Monitoring-stored-grain-on-farm.pdf. See also GRDC (2011) Stored gain pests identification: the back-pocket guide. GRDC, http://storedgrain.com.au/wp-content/uploads/2013/05/Stored-grain-pests_NorthSouthWest_Pocketguide.pdf

VIDEOS

WATCH: GCTV2: Grain storage insect ID

MORE INFORMATION

Identification of insect pests in stored grain

Stored grain pests identification: the back-pocket guide

Monitoring stored grain on farm

Why identify stored insect grain pests?

Most insect-control methods for stored grain work against all species, so you don't need to identify the storage pests to make decisions about most control methods. But if you intend to spray grain with insecticides you may need to know which species are present if:

- A previous application has failed, and you want to know whether resistance was the reason—if more than one species survived, resistance is unlikely to be the cause.
- You intend to use a residual protectant to treat infested grain—pyrimiphos-methyl, fenitrothion and chlorpyrifos-methyl are ineffective against lesser grain borer, and pyrimiphos-methyl and fenitrothion are generally ineffective against saw-toothed grain beetles.
- You intend using dichlorvos to treat infested grain—if lesser grain borers are present you need to apply the higher dose rate, which increases the withholding period before grain can be marketed from seven days to 28 days.

13.2.3 Monitoring grain for pests

Damage by grain insect pests often goes unnoticed until the grain is removed from storage. Regular monitoring will help to ensure that grain quality is maintained.

- Sample grain in each storage at least monthly. During warmer periods of the year, fortnightly sampling is recommended.
- Take samples from the top and bottom of grain stores and sieve using 2 mm mesh onto a white tray to separate any insects (Photo 4).
- Hold the tray in sunlight for 10–20 seconds to trigger movement of any insects, making them easier to see. Use a magnifying glass to identify them.
- Grain probes or pitfall traps should also be used to check for insects. Traps are left in the grain during storage and are often able to be used to detect the start of an infestation.
- Push the probe or trap into the grain surface, pull up, and inspect for insects. Conduct inspection fortnightly or monthly at most. Place 1–2 traps in the top of a silo or several traps in a grain shed.
- Be sure to check the grain three weeks before sale to allow time for treatment if required. [16]

Photo 4: *A 2 mm mesh sieve will separate insects from grain.*

Source: Plant Health Australia.

13.2.4 Hygiene

Key points:

- Effective grain hygiene requires the complete removal of all waste grain from storages and equipment.

16 Plant Health Australia (2015) Monitoring stored grain on farm. Plant Health Australia, http://www.planthealthaustralia.com.au/wp-content/uploads/2017/05/Monitoring-stored-grain-on-farm-2017.pdf

- Be meticulous with grain hygiene: pests only need a small amount of grain for survival.

In a year, a bag of infested grain can produce more than one million insects, which can walk and fly to other grain storages, where they will start new infestations. Therefore, meticulous grain hygiene is vital. It involves removing any grain that can harbour pests and allow them to breed. It also includes regular inspection of seed and stockfeed grain so that any infestations can be controlled before the pests spread.

Where to clean

Grain pests live in dark, sheltered areas and breed best in warm conditions. They are commonly found in:

- empty silos and grain storages
- aeration ducts, augers and conveyers
- harvesters, field bins and chaser bins
- left-over bags of grain trucks
- spilt grain around grain storages
- equipment and rubbish around storages
- seed grain
- stockfeed grain [17]

Successful grain hygiene involves cleaning all areas where grain gets trapped in storages and equipment (Photo 5). Grain pests can survive in a tiny amount of grain, so any parcel of fresh grain, wherever it is, can become infested, and a source of infestation elsewhere.

Photo 5: *Grain left in trucks is an ideal place for grain pests to breed. Keep trucks, field bins and chaser bins clean.*

Source: GRDC

When to clean

Straight after harvest is the best time to clean grain-handling equipment and storages, before insects have a chance to breed. In a trial carried out in Queensland, more than 1,000 lesser grain borers were counted in the first 40 litres of grain through a harvester at the start of harvest—and the harvested had been considered to be reasonably clean at the end of the previous season. Discarding the first few bags of grain at the start of the next harvest is a good idea. Further studies in Queensland revealed that insects are least mobile during the colder months of the year. Farmers

17 Stored Grain Information Hub (2013) Hygiene and structural treatments for grain storages. Fact sheet. GRDC, http://storedgrain.com.au/hygiene-structural-treatments/

can take advantage of this by cleaning around silos in July–August to reduce insect numbers before they become mobile.

How to clean

The better the cleaning job, the less chance there is of pests being harboured. The best ways to get rid of all grain residues use a combination of:

- sweeping
- vacuuming
- compressed air
- blow or vacuum guns
- pressure washers
- fire-fighting hoses

Using a broom or compressed air gets rid of most grain residues (Photo 6), and a follow-up wash-down removes grain and dust left in crevices and hard-to-reach spots. Choose a warm, dry day to wash storages and equipment so they dry out quickly (which helps to prevent rusting). When inspecting empty storages, look for ways to make the structures easier to keep clean. Seal or fill any cracks and crevices to prevent grain lodging there and becoming a harbour for insects. Bags of left-over grain lying around storages and in sheds create a perfect harbour and breeding ground for storage pests. After collecting spilt grain and residues, dispose of them well away from any grain-storage areas.

A concrete slab underneath silos makes cleaning much easier (Photo 7).

Photo 6: *Clean silos, including the silo wall, with air or water to provide a residue-free surface to apply structural treatments.*

Source: GRDC

The process of cleaning on-farm storages and handling equipment should start with the physical removal, blowing out or hosing out of all residues. Once the structure is clean and dry, consider the application of diatomaceous earth (DE) as a structural treatment. (See Section 1.2.4 Structural treatments below for more information.)

VIDEOS

WATCH: Grain Silo Hygiene.

MORE INFORMATION

Aeration cooling for pest control

Photo 7: *A concrete slab under silo makes cleaning up spilled grain much easier.*

Source: GRDC

13.2.5 Aeration cooling for pest control

While adult insects can survive at low temperatures, most juveniles stop developing at temperatures below 18–20°C (Table 3). At temperatures below 15°C, the common rice weevil stops developing.

At low temperatures insect life cycles (i.e. egg, larvae, pupae and adult) are lengthened from the typical four weeks at warm temperatures (30–35°C) to 12–17 weeks at cooler temperatures (20–23°C). [18] (See Section 13.3.2 Aeration cooling, below, for more information.)

Table 3: *The effect of grain temperature on insects and mould.*

Grain temp (°C)	Insect and mould development	Grain moisture content (%)
40–55	Seed damage occurs, reducing viability	
30–40	Mould and insects are prolific	>18
25–30	Mould and insects are active	13–18
20–25	Mould development is limited	10–13
18–20	Young insects stop developing	9
<15	Most insects stop reproducing, mould stops developing	<8

Source: Kondinin Group

13.2.6 Structural treatments

Key points:

- Structural treatments, such as diatomaceous earth (DE), can be used on storages and equipment to protect against grain pests.
- Check delivery requirements before using chemical treatments.

18 Stored Grain Information Hub (2014) Aeration cooling for pest control. Fact sheet. GRDC, http://storedgrain.com.au/aeration-cooling/

MORE INFORMATION

Hygiene and structural treatments for grain storages

Managing maximum residue limits in export grain

To avoid the high risk of exceeding the maximum residue limits for crops, it is recommended that chemical treatments, even in structural treatments, be avoided for all grains.

A better option is to use diatomaceous earth (DE) also known as inert dust, as a structural treatment. It is important to wash and dry the storage and equipment that has come into contact with DE before using them. This will ensure the DE doesn't discolour the grain surface. Diatomaceous earth is an amorphous silica. (A commonly available commercial formulation is Dryacide®.) DE acts by absorbing the insect's cuticle, or protective waxy exterior, causing death by desiccation. If applied correctly, DE can provide up to 12 months of protection for storages and equipment.

If unsure, check with the grain buyer before using any product that will come in contact with the stored grain. [19]

Applying to silos

Inert dust requires a moving air-stream to direct it onto the surface being treated; alternatively, it can be mixed into a slurry with water and sprayed onto the surface. Read and follow the label directions. Throwing dust into silos by hand will not achieve an even coverage, so will not be effective. For very small grain silos and bins, a hand-operated duster, such as a bellows duster, is suitable. Larger silos and storages require a powered duster operated by compressed air or a fan. If compressed air is available, it is the most economical and suitable option for use on the farm; connected it to a Venturi duster (e.g. the Blovac BV-22 gun) (Photo 8).

Photo 8: *A blower and vacuum gun such as the Venturi gun is the best applicator for inert dusts. Aim for an even coat of diatomaceous earth across the roof, walls and base.*

Photo: C. Warrick, Proadvice

The application rate is calculated at 2 g/m^2 of the surface being treated (Table 4). Although the dust is inert, breathing in excessive amounts of it is not ideal, so use a disposable dust mask and goggles during application.

Apply DE in silos, starting at the top (and following OH&S procedures), and coating the inside of the roof then working your way down the silo walls, and finishing by

VIDEOS

WATCH: GCTV7: Applying diatomaceous earth demonstration

19 Stored Grain Information Hub (2014) Storing Pulses. Fact sheet. Revised. GRDC, http://storedgrain.com.au/storing-pulses/

MORE INFORMATION

Hygiene and structural treatment for grain storages.

pointing the stream at the bottom of the silo. If silos are fitted with aeration systems, distribute the inert dust into the ducting without getting it into the motor, where it could cause damage. [20]

Table 4: *Diatomaceous earth application guide.*

Storage capacity (t)	DE quantity (kg)
20	0.12
56	0.25
112	0.42
224	0.60
450	1.00
900	1.70
1800	2.60

13.2.7 Fumigation

There are a number of chemical options for the control of grain pests in stored cereals (Table 5) [21].

Table 5: *Resistance and efficacy guide for stored-grain insects.*

Treatment and example product	WHP	Lesser grain borer	Rust-red flour beetle	Rice weevil	Saw-toothed grain beetle	Flat grain beetle	Psocids (booklice)	Structural treatments
Grain disinfestants—used on infested grain to control full life cycle (adults, eggs, larvae, pupae)								
Phosphine (Fumitoxin®)[1,3] when used in gas-tight, sealable stores	2	Effective control	Effective control	Effective control	Effective control	High-level resistance	Effective control	Not registered for this pest
Sulfuryl fluoride (ProFume®)[10]	1	Effective control	Effective control	Effective control	Effective control	Effective control	Not registered for this pest	Not registered for this pest
Grain protectants—applied postharvest. Poor adult control if applied to infested grain								
Pirimiphos-methyl (Actellic 900®)	nil[2]	Not registered for this pest	Effective control	Effective control	Resistance widespread	Effective control	Not registered for this pest	Resistant species likely to survive
Fenitrothion (Fenitrothion 1000®)[4, 7]	1–90	Not registered for this pest	Effective control	Effective control	Resistance widespread	Not registered for this pest	Not registered for this pest	Resistant species likely to survive
Chlorpyrifos-methyl (Reldan Grain Protector®)[5]	Nil[2]	Resistance widespread	Effective control	Effective control	Resistance widespread	Not registered for this pest	Not registered for this pest	Resistant species likely to survive
'Combined products' (Reldan Plus IGR Grain Protector)	Nil[2]	Resistance widespread	Effective control	Effective control	Effective control	Not registered for this pest	Not registered for this pest	Resistant species likely to survive
Deltamethrin (K-Obiol®)[10]	Nil[2]	Effective control	Effective control	Resistance widespread	Effective control	Effective control	Not registered for this pest	Not registered for this pest
Spinosad and Chlorpyrifos-methyl (eg Conserve On-Form™)[9]		Effective control	Effective control	Effective control	Effective control	Effective control	Not registered for this pest	Not registered for this pest
Diatomaceous earth, amorphous silica—effective internal structural treatment for storages and equipment. Specific-use grain treatments								
Diatomaceous earth, amorphous silica (Dryacide®)[8]	Nil[2]	Effective control	Effective control	Effective control	Effective control	Not registered for this pest	Not registered for this pest	Effective control

Not registered for this pest
High-level resistance in flat grain beetle has been identified, send insects for testing if fumigation failures occur
Resistant species likely to survive this structural treatment for storage and equipment
Resistance widespread (unlikely to be effective)
Effective control

1 Unlikely to be effective in unsealed sites, causing resistance, see label for definitions
2 When used as directed on label
3 Total of (exposure + ventilation + withholding) = 10 to 27 days
4 Nufarm label only
5 Stored grains except malting barley and rice/ stored lupins registration for Victoria only/ not on stored maize destined for export
6 When applied as directed, do not move treated grain for 24 hours
7 Periods of 6–9 months storage including mixture in adulticide (e.g. Fenitrothion at label rate

20 Pulse Australia (2013) Northern Chickpea—Best Management Practices Training Course Manual 2013. Pulse Australia.

21 Stored Grain Information Hub (2016) Grain storage pest control guide—northern and southern regions. Fact sheet. GRDC, http://storedgrain.com.au/wp-content/uploads/2016/10/GSFS-1A_GSPestControl_NS_R3.pdf

8 Do not use on stored maize destined for export, or on grain delivered to bulk-handling authorities
9 Dichlorvos 500 g/L registration only
10 Restricted to licensed fumigators or approved users
11 Restriced to use under permit 14075 only. Unlikely to be practical for use on farm

Source: Registration information courtesy of Pestgenie, APVMA and InfoPest (DEEDI) websites

Source: GRDC

It is important to apply fumigants according to the label instructions. Before applying, also check with your grain buyers or bulk handlers for their requirements. Taking fumigation shortcuts may kill enough adult insects in grain so it passes delivery standards, but if poor fumigation techniques result in failure to kill pests at all stages of their life cycle, grain will soon be reinfested once the larvae and eggs develop.

The repercussions of such practices are detrimental to the grains industry. Grain may be rejected at receival. What's worse, every time a poor fumigation is carried out, insects with some resistance survive, making the chemical less effective in the future.

Photo 9: *Phosphine is widely accepted as having no residue problems.*

Photo: DAF Qld

Fumigation with phosphine is a common component of many integrated pest-control strategies (Figure 13).

While there is some insect resistance to phosphine, it is widely accepted because it causes no residue problems for grain or pulses. The grains industry has adopted a voluntary strategy to manage the build-up of phosphine resistance in pests. Its core recommendations are to limit the number of conventional phosphine fumigations on undisturbed grain to three per year, and to employ a break strategy. [22]

Maximum residue limits

By observing several precautions, growers can ensure that grain coming off their farm is compliant with the maximum pesticide residue limits that apply to Australian exports. Violations of maximum residue limits (MRLs) affect the marketability of Australian grain exports, and consequences may include costs being imposed on exporters and/or growers.

Measures growers need to take to avoid MRL violations are detailed in a new *Grain Marketing and Pesticide Residues* Fact Sheet, produced by the Grains Research

VIDEOS

WATCH: GCTV Stored Grain. Fumigation recirculation.

22 P Collins (2009) Strategy to manage resistance to phosphine in the Australian grain industry. Cooperative Research Centre for National Plant Biosecurity, http://www.graintrade.org.au/sites/default/files/file/NWPGP/NWPGP%202017/Chemical%20Resistence%20Management%20Strategy%20-%20June%202017.pdf

MORE INFORMATION

Managing MRLs factsheet

Fumigating with phosphine, other fumigants and controlled atmospheres

Grain fumigation – a guide.

Fumigation to control insects in stored grain

VIDEOS

WATCH: GCTV Stored Grain: Phosphine Dose Rates.

and Development Corporation (GRDC). The Fact Sheet states it is essential that both pre-harvest and post-harvest chemical applications adhere to the Australian Grain Industry Code of Practice, only registered products are used and all label recommendations, including rates and withholding periods, must be observed. Other key points include:

- Trucks or augers that have been used to transport treated seed or fertiliser can be a source of contamination – pay particular attention to storage and transport hygiene;
- Silos that have held treated fertiliser or pickled grain will have dust remnants – these silos either need to be cleaned or designated as non-food grade storage;
- Know the destination of your grain. When signing contracts, check the importing countries' MRLs to determine what pesticides are permitted on a particular crop. [23]

Phosphine application

For effective phosphine fumigation, a minimum of 300 parts per million (ppm) gas concentration for seven days or 200 ppm for 10 days is required. Fumigation trials in silos with small leaks demonstrated that phosphine levels are as low as 3 ppm close to the leaks. The rest of the silo also suffers from reduced gas levels.

Where to apply

Achieve effective fumigation by placing the correct phosphine dose (as directed on the label) onto a tray and hanging it in the headspace of a pressure-tested, sealed silo, or into a ground-level application system if the silo is fitted with recirculation.

Arrange the tablets so that as much surface area as possible is exposed to air; this helps the gas disperse freely throughout the grain stack. Spread the phosphine tablets evenly across trays. Hang bag chains in the head space or roll out flat on the top of the grain so air can freely pass around the tablets as the gas dissipates. Bottom-application facilities must have a passive or active air-circulation system to carry the phosphine gas out of the confined space as it evolves. Without air movement in a confined space, phosphine can become explosive.

Time to kill

To control pests at all life stages and prevent insect resistance, phosphine-gas concentration need to reach 300 parts per million (ppm) for seven days when grain is above 25°C, or 200 ppm for 10 days for grain at 15–25°C. In cooler temperatures, insect activity is slower, so they must be exposed to the gas for longer. [24]

After fumigation, ventilate grain for a minimum of one day with aeration fans running, or five days if no fans are fitted.

A minimum withholding period of two days is required after ventilation before grain can be used for human consumption or stockfeed.

The total time needed for fumigating is 10–17 days.

As a general rule, only keep a silo sealed while carrying out the fumigation (e.g., one to two weeks). After fumigation has been completed, return to aeration cooling to hold the stored grain at a suitable temperature.

Handle with care

Phosphine is a highly toxic gas with potentially fatal consequences if handled incorrectly. As a minimum requirement, the label directs the use of cotton overalls buttoned at the neck and wrist, eye protection, elbow-length PVC gloves, and a breathing respirator with combined dust and gas cartridge.

23 S Watt. (2014). Know your maximum residue limits. https://grdc.com.au/Media-Centre/Media-News/South/2014/07/Know-your-maximum-residue-limits

24 GRDC Stored Grain Information Hub. Grain Fumigation – A guide. http://storedgrain.com.au/fumigation-guide/

Non-chemical treatments

The two non-chemical treatments available both use controlled atmospheres to kill pests. They are:

- carbon dioxide
- nitrogen

Treatment with carbon dioxide (CO_2) involves displacing the oxygen inside a gas-tight silo with CO_2, to create a toxic atmosphere to grain pests. To achieve a complete kill of all the main grain pests at all life stages, CO_2 must be retained at a minimum concentration of 35% for 15 days.

Grain stored under nitrogen (N_2) also provides insect control while preserving grain quality without chemicals. It is safe to use and more environmentally acceptable than CO_2 because of the CO_2's contribution to greenhouse gases. The main operating cost is the capital cost of equipment and electricity. It also produces no residues, so grains can be traded at any time, in contrast to chemical fumigants, which have withholding periods. Insect control with N_2 involves a process using pressure swinging adsorption (PSA) technology, which modifies the atmosphere in the grain storage to remove everything except N_2 , thus starving the pests of oxygen. [25]

13.3 Aeration during storage

13.3.1 Dealing with high-moisture grain

Key points:

- Deal with high-moisture grain promptly.
- Monitoring grain moisture and temperature daily will enable the early detection of mould and insects.
- Aeration drying requires airflow rates in excess of 15 L/s/t.
- Dedicated-batch or continuous-flow dryers are a more reliable way to dry grain than aeration drying in less-than-ideal ambient conditions.

The Queensland Department of Employment, Economic Development and Innovation conducted a trial that revealed that high-moisture grain generates heat when put into a confined storage, such as a silo. Cereal grain with 16.5% MC and a temperature of 28°C was put into a silo with no aeration. Within hours, the grain temperature had reached 39°C, and within two days had reached 46°C, providing ideal conditions for mould growth and grain damage (Figure 5).

Grain that is over the standard safe storage moisture content of 12.5% can be dealt with by:

- Blending—mix high-moisture grain with low-moisture grain, then aerate.
- Aeration cooling—grain of moderate moisture, up to 15% MC, can be held for a short term under aeration cooling until drying equipment is available.
- Aeration drying—use large volumes of air to force a drying front through the grain in storage, to slowly remove moisture. Supplementary heating can be added.
- Continuous flow drying—grain is transferred through a dryer, which uses a high volume of heated air to pass through a continuous flow of grain.
- Batch drying—usually a transportable trailer dries 10–20 tonnes of grain at a time, using a high volume of heated air, which passes through the grain and out through perforated walls.

25 C Warrick (2011) Fumigating with phosphine, other fumigants and controlled atmospheres: Do it right—do it once. A Grains Industry Guide. GRDC, https://grdc.com.au/__data/assets/pdf_file/0025/206791/fumigating-with-phosphine.pdf.pdf

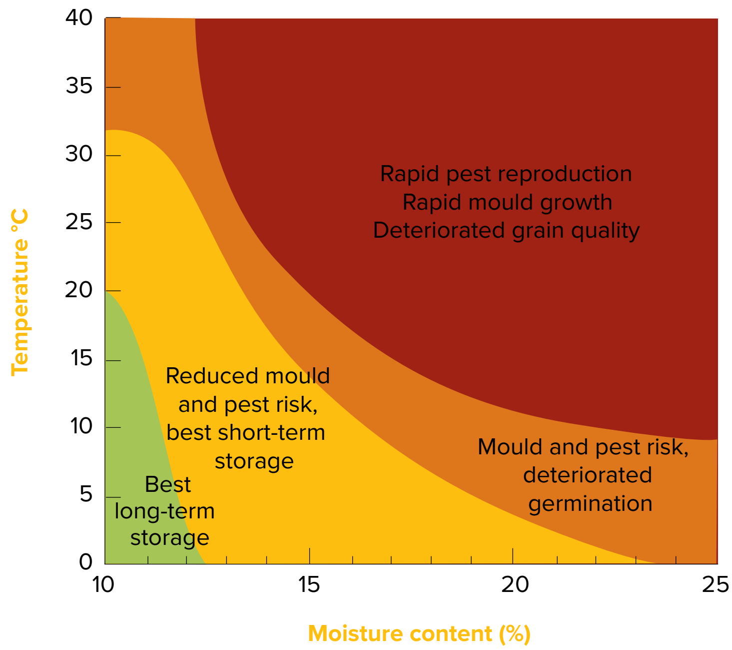


Figure 5: *Effects of temperature and moisture on stored grain.*

Source: CSIRO Ecosystems Sciences

13.3.2 Aeration cooling

Key points:

- Grain temperatures below 20°C significantly reduce mould and insect development.
- Reducing grain temperature with aeration cooling protects seed viability.
- Controlling aeration cooling is a three-stage process: continuous, rapid, and then maintenance.
- Stop aeration if ambient, relative humidity exceeds 85%.
- Automatic grain-aeration controllers that select optimum fan running times provide the most reliable results.

Aeration cooling can be used to reduce the risk of mould and insect development for a month or two until drying equipment is available to dry grain down to a safe level for long-term storage or delivery. In most circumstances, grain can be stored safely at up to 14–15% MC with aeration cooling fans running continuously, and delivering at least 2–3 L/s/t. It is important to keep fans running continuously for the entire period, only stopping them if the ambient relative humidity is above 85% for more than about 12 hours. If aeration fans run for longer than this in humid weather, they will cause the grain to become wet.

Blending

Blending is the principle of mixing slightly over-moist grain with lower-moisture grain to achieve an average moisture content below the ideal of 12.5%. It is a successful technique for grain moisture content levels up to 13.5%, and can be an inexpensive way of dealing with wet grain, providing the infrastructure is available. Aeration cooling does allow blending in layers, but if aeration cooling is not available blending must be evenly distributed (see Figure 6). [26]

26 Stored Grain Information Hub (2013) Dealing with high moisture grain. Fact sheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

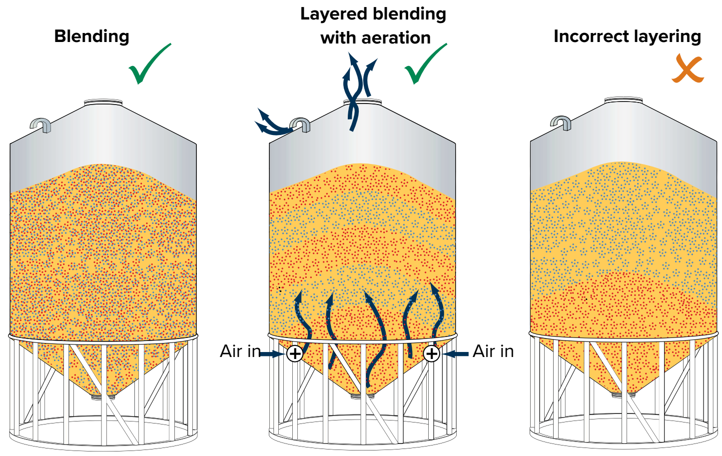


Figure 6: *Diagram demonstrating the correct practices for blending.*

Source: Kondinin Group

Seed viability

Research trials reveal that wheat at 12% MC stored for six months at 30–35°C (unaerated grain temperature) will have reduced germination percentage and seedling vigour.

13.3.3 Aeration drying

Aeration drying relies on high air volume and is usually done in a purpose-built drying silo or a partly filled silo with high-capacity aeration fans. It is a slow process and relies on having:

- high airflow rates
- well-designed ducting for even airflow through the grain
- exhaust vents in the silo roof, and
- warm, dry weather conditions.

It is important to seek reliable advice on equipment requirements and the correct management of fan running times, otherwise there is a high risk of damaging the grain, to the detriment of quality.

High airflow for drying

Unlike aeration cooling, aeration drying requires high airflow, in excess of 15 L/s/t, to move drying fronts quickly through the whole grain profile and depth to carry moisture out of the grain bulk. As air passes through the grain, it collects moisture and forms a drying front. If the airflow is too low, the drying front will take too long to reach the top of the grain stack; this is often referred to as a 'stalled drying front'. Providing the storage has sufficient aeration ducting, a drying front can pass through a shallow stack of grain much faster than a deep stack. As air will take the path of least resistance, make sure the grain is spread to an even depth.

Ducting for drying

The way to avoid hot spots is with adequate ducting to deliver an evenly distributed flow of air through the entire grain stack (Photo 10). A flat-bottomed silo with a full floor-aeration plenum is ideal providing it can deliver at least 15 L/s/t of airflow. The silo may only be able to be part filled, which in many cases is better than trying to dry grain in a cone-bottomed silo with insufficient ducting.

VIDEOS

WATCH: GCTV2: Grain storage cooling aeration

MORE INFORMATION

GRDC Aerating stored grain: Cooling or drying for quality control.

Photo 10: *A flat-bottomed silo designed for aeration drying.*

Source: GRDC

Venting for drying

Adequate ventilation maximises airflow and allows moisture to escape rather than forming condensation on the underside of the roof and wetting the grain on the top of the stack. The amount of moisture that has to be able to escape with the exhaust air is 10 L for every 1% MC removed per tonne of grain.

Weather conditions for drying

For moisture transfer (i.e. drying) to occur, air with a lower relative humidity than the grain's equilibrium moisture content must be used. For example, wheat at 25°C and 14% MC has an equilibrium point of the air around it at 70% relative humidity (Table 6). In order to dry this wheat from its current state, the aeration drying fans would need to be turned on when the ambient air was below 70% relative humidity.

Table 6: *Equilibrium moisture content for wheat.*

Relative humidity (%)	Temperature 15	25	35
	Grain moisture content %)		
30	9.8	9.0	8.5
40	11.0	10.3	9.7
50	12.1	11.4	10.7
60	13.4	12.8	12.0
70	15.0	14.0	13.5

Note: values may be different for rye grain.

Source: GRDC

VIDEOS

WATCH: GCTV5: Aeration drying—getting it right

MORE INFORMATION

Dealing with high moisture grain

Phase one of drying

Aeration drying fans can be turned on as soon as the aeration ducting is covered with grain. They are left running continuously until the air coming out of the top of the storage has a clean, fresh smell. The only time drying fans are to be turned off during this phase is if ambient air exceeds 85% relative humidity for more than a few hours.

Phase two of drying

By monitoring the temperature and moisture content of the grain, and referring to an equilibrium moisture table, such as Table 6, a suitable relative-humidity trigger point can be set. As the grain dries the equilibrium point will fall, so the relative-humidity trigger point will need to be reduced to dry down the grain further.

Reducing the relative-humidity trigger point slowly during phase two will help keep the difference in grain moisture from the bottom to the top of the stack to a minimum, by ensuring the fans get adequate running time to push each drying front through the entire grain stack.

Supplementary heating

Heat can be added to aeration drying in proportion to the airflow rate. Higher airflow rates allow more heat to be added as it will push each drying front through the storage fast enough to avoid overheating the grain close to the aeration ducting. As a general guide to avoid overheating this grain, inlet air shouldn't exceed 35°C.

Cooling after drying

Regardless of whether supplementary heat is added during the process, the grain should be cooled immediately after it has been dried to the desired level. [27]

13.3.4 Aeration controllers

Aeration controllers manage aeration drying, cooling and maintenance functions in up to 10 storages (Photo 11). The unit takes into account the moisture content and temperature of grain at loading and the desired grain condition after time in storage, and selects appropriate settings to achieve safe storage levels. [28]

Research carried out by the then Department of Agriculture, Fisheries and Forestry Queensland showed that, with the support of a controller, aeration can rapidly reduce stored-grain temperatures to a level that helps maintain grain quality and inhibits insect development.

During trials where grain was harvested at 30°C and 15.5% MC, grain temperatures rose to 40°C within hours of being put into storage. An aeration controller was used to rapidly cool grain to 20°C, and then hold it between 17°C and 24°C from November to March.

To replicate these results on the farm, growers need to:

- Know the capacity of their existing aeration system.
- Determine whether grain requires drying before cooling can be carried out.
- Understand the effects of relative humidity and temperature when aerating stored grain.
- Determine the target conditions for the stored grain.

27 Stored Grain Information Hub (2013) Dealing with high moisture grain. Fact sheet. GRDC, http://storedgrain.com.au/dealing-with-high-moisture-grain/

28 GRDC (2007) New generation aeration controller. Ground Cover. Issue 57. GRDC, https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-57-Grain-Storage-Supplement/New-generation-aeration-controller

VIDEOS

WATCH: Grain storage with Phillip Burrill—using aeration controllers.

Photo 11: *Automatic aeration controllers such as this one are not only the most effective way to cool grain, one unit can manage up to 10 storages.*

Source: GRDC

13.4 Grain protectants for storage

The widespread resistance of the lesser grain borer (*Rhyzopertha dominica)* to grain protectants is being halted with the availability of deltamethrin (e.g. K-Obiol® EC Combi) and spinosad (e.g. Conserve™ On-Farm) products for use on farms.

13.4.1 K-Obiol® EC Combi

K-Obiol® EC Combi is a synergised grain protectant for use on cereal grains, malting barley and sorghum. [29] It can be used in any type of storage, sealed or unsealed. It is suitable for use by grain growers and grain accumulators. Like all protectants it is a liquid and must be evenly applied as a dilution to the grain as it is fed into the storage. It is for use on un-infested grain and is not recommended for eradicating insect pests when they have infested grain.

The active constituent is deltamethrin. [30] Piperonyl butoxide is added as a synergist; i.e. it increases the effectiveness of the deltamethrin. Because the product is based on deltamethrin, there are none of the insect-resistance problems that growers and bulk handlers have with other protectants.

Because protectants are residual, grain end-users will be concerned to ensure that the grain does not contain excessive levels of chemicals. This would normally come about from incorrect treatment or double treatment as the grain moves along the supply chain. To protect the end-user, and ultimately Australian grain growers, a product stewardship program has been developed to ensure the correct use of the product. The program also aims to ensure the product is used in the way that minimises the development of insect resistance and increases it usable life. [31]

13.4.2 Conserve™ On-farm

Conserve™ On-Farm is a grain protectant from Dow AgroSciences that has three active ingredients to control most major insect pests of stored grain, including the resistant lesser grain borer (LGB). [32] It provides six to nine months of control and has

29 Stored Grain Information Hub (n.d.) K-Obiol Combi. GRDC, http://storedgrain.com.au/k-obiol-combi/

30 Bayer (n.d.) Welcome to K-Obiol. Bayer, http://www.k-obiol.com.au/

31 GRDC Stored Grain information hub. K-Obiol Combi. http://storedgrain.com.au/k-obiol-combi/

32 Dow AgroSciences (n.d.) Conserve™ On-Farm, Conserve™ Plus. Dow AgroSciences, http://www.conserveonfarm.com.au/en

no withholding period (WHP). Maximum residue limits (MRLs) have been established with key trading partners and there are no meat-residue bioaccumulation problems.

Conserve™ On-Farm is a combination product of two parts that are mixed before application. Using Part A and Part B together is very important to get control of the complete spectrum of insects. They comprise:

- Part A, 1 x 5 L of chlorpyrifos-methyl and S-methoprene—controls all stored grain insect pests other than the resistant lesser grain borer (*Rhyzopertha dominica*)
- Part B, 2 x 1 L of spinosad—is very effective on the lesser grain borer, including resistant strains, but has little to no activity on other key species. [33]

33 Stored Grain Information Hub (n.d.) Conserve. GRDC, http://storedgrain.com.au/conserve-farm/